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# THE NATURALISED FLORA OF SOUTH AUSTRALIA 3. ITS ORIGIN, INTRODUCTION, DISTRIBUTION, GROWTH FORMS AND SIGNIFICANCE

P.M. Kloot

South Australian Department of Agriculture,
GPO Box 1671, Adelaide, South Australia 5001

## Abstract

Some features of the South Australian naturalised flora were examined. The predominant source of naturalised alien species has changed from Europe or Eurasia in 1855 to the Mediterranean and environmentally similar areas at present. It is suggested that this is due to the history of northern European settlement of South Australia and the attendant importation of plants from that region. The majority of presently naturalised plants were recorded in Great Britain at the time of South Australian settlement and it is suggested that regardless of their ultimate origin, most plants would have arrived via Great Britain or, more generally, northern Europe. The majority of naturalised plants have been documented or are suspected to have been introduced intentionally. Most of them were ornamental, fodder or culinary plants. Of the unintentionally introduced species, most were fleece, seed or ballast contaminants. A number of characteristic distribution patterns of naturalised plants in South Australia are recognized. These result from climatic and edaphic features and from patterns of land use. Annuals are the predominant growth form of the well-established species. The majority of the unintentionally introduced species are annuals.

## Introduction

The development of the South Australian alien flora since colonization (Kloot, 1987) was ascertained from the documentation discovered during an intensive search (Kloot, 1987) to locate more material than was thought available hitherto (Michael, 1972). In this paper the changes in its geographical origins since 1855 are examined and compared with those in other environmentally similar regions. Additionally the present naturalised flora (Kloot, 1986) is analysed with respect to its route of introduction, reasons for introduction, its distribution patterns in the State, growth form and importance in the total flora.

## The Geographical Origins of the Naturalised Flora

### Data

In this section, changes are demonstrated in the proportion of the naturalised flora originating from different regions of the world. The data used are derived from the checklist (Kloot, 1986) except for 1855, for which (Kloot, 1983) is used as the base, being more complete as explained earlier (Kloot, 1987). The origins of the plants listed as naturalised in 1855, 1909, 1929, 1965 and 1984 are shown in Table 1.

### Discussion

The figures shown in Table 1 show some consistent trends. Firstly, there has been a steady fall in the proportion of species originating from Europe and Western Asia outside the Mediterranean basin, although the proportion from the Mediterranean itself has stayed remarkably constant since 1909. Secondly, the percentage of plants originating from South Africa has risen consistently. Thirdly, the proportion of plants from the Americas has risen but the number and proportions from South America have always exceeded those from North America.

South Australia was settled by Northern Europeans largely migrating directly from that region. It is understandable therefore that the weeds originating in the same areas would have the best opportunity for early transportation to the new settlement. With time, plants originating from areas more akin environmentally to South Australia found their way here and became established, altering the proportions as shown in Table 1. Apart from South African species that reached South Australia via Europe, the stopover of many ships at South African ports on the way to Australia, particularly prior to the opening of the Suez Canal, facilitated the movement of local plants to Australia. This could have occurred by contamination of fodder loaded there, e.g. *Emex australis*, *Pentzia suffruticosa* and probably *Cyperus tenellus*, or adhering to animals or humans e.g. *Cotula* spp., *Arctotheca calendula*. Intentional movement is also implicated, particularly in the case of ornamentals (e.g. Aizoaceae) or potentially useful plants (e.g. *Ehrharta* spp.)

The same argument applies to South America, for many ships stopped at South American ports, particularly Rio de Janiero and Buenos Aires, before heading for the Cape of Good Hope, or sailing further south and making directly for Australia (Charlwood, 1981). Also sailing ships returning to Europe often went around Cape Horn and then called at South American ports. These ships eventually returned to Australia and some contamination leading to the transport of propagules is at least theoretically possible.

Conversely, the proportion of North American species has always been low. There was no regular direct link between there and South Australia. Almost all of the North American species listed for South Australia are also found in Europe (Tutin *et al.*, 1964-1980) which suggests that these plants reached Australia via Europe. The movement of fodder from North America, which on a large scale at least was rather erratic, could have been responsible for the arrival of some species that became successfully naturalised afterwards. *Solanum elaeagnifolium* appears to be such an example, as it is believed to have been brought, to South Australia at least, in hay imported from North America during the 1914 drought.

Willis (1972) remarked that no North American species of *Trifolium* had been introduced (? become established) in Victoria. It should be noted that none of these species have become established in Europe either (Tutin *et al.*, 1968). As these species have not been commercialised, there appears to be no intentional movement of propagules and they do not seem to have transport mechanisms to facilitate their movement.

Everist (1959) convincingly demonstrated that settlers' origins affected the composition of the alien flora. He showed that the alien flora of Queensland at that time was predominantly temperate in origin, although the local environment is basically sub-tropical. Later, the development of agricultural systems based on sub-tropical pastures and crops necessitated the import of large quantities of seeds from similar environments. Consequently the proportion of sub-tropical species established in Queensland has risen sharply (Kleinschmidt and Johnson, 1977).

The settlement of the mediterranean areas of the world also demonstrates this effect. South Africa (Wells & Stirton, 1982) and southern Australia were settled by northern Europeans, viz. the Dutch, English and Germans. Their naturalised floras showed the same general trends in the change from a high proportion of European species to those of more specifically Mediterranean origins. However, California and Chile were both initially settled by the Spanish. They had similar naturalised floras (Solbrig *et al.*, 1977) which always had a high proportion of Mediterranean species (Gulmon, 1977), which for California at least, were specifically noted as originating chiefly in Spain (Naveh, 1967).

One striking difference between Australian and other mediterranean areas is in the proportion of indigenous weeds. The following figures (after Wells and Stirton, 1982) of the number of families, genera and species of introduced and indigenous weeds in South Africa demonstrate this point.

| | Families | Genera | Species |
|---|---|---|---|
| | No. (%) | No. (%) | No.(%) |
| Exotic weeds | 78 (51) | 284 (57) | 503 (57) |
| Indigenous weeds | 75 (49) | 211 (43) | 381 (43) |

Comparable figures for South Australia after Kloot (1985a) are:-

| | Families | Genera | Species |
|---|---|---|---|
| | No. (%) | No. (%) | No. (%) |
| Exotic species | 88 (85) | 448 (95) | 875 (95) |
| Indigenous species | 16 (15) | 26 (5) | c.50 (5) |

**Routes of Introduction to South Australia**

The present South Australian alien flora originated predominantly in other mediterranean regions with which, historically, there was very little direct contact apart from South Africa. It is clear therefore that apart from a limited number of species that were imported directly as potential fodder plants, and generally only in the last fifty years or so, the vast majority of these plants must have reached South Australia via a circuitous route. The species concerned must have been transported intentionally or otherwise, to a third region from which they were then moved again, on purpose or accidentally, to South Australia. The same argument applies for other regions from which members of the alien flora originated, e.g. China, East Africa.

Because South Australia was settled from northern Europe, and in particular Britain, it is reasonable to assume that those localities would be the staging posts from which plants were moved to South Australia. It is remarkable that of the 904 alien species, at least 765 were native to Britain or had been introduced and grown there by the 1830s (Loudon, 1830). This fact is not conclusive proof that all these plants were actually introduced to South Australia from Britain. However it certainly would apply for most of the intentional introductions such as the ornamental bulbs from South Africa and probably even such Australian ornamentals as *Sollya heterophylla*, *Pittosporum undulatum* and *Albizia lophantha* which had all been introduced to the British horticultural trade before the colonization of South Australia (Loudon, 1830). Their early appearance in local horticultural catalogues alongside other material imported from Britain (McEwin, 1843; Bailey, 1845) is strong evidence that their introduction to South Australia was via Britain.

The alien flora may be categorised as to its route of introduction as follows:

(a) Plants intentionally introduced or native to Britain where they were used for one or more purposes and then introduced intentionally to South Australia such as ornamentals, crop and fodder plants.

In some cases, such plants subsequently escaped and became naturalised in Britain and then did so in South Australia, e.g. *Briza maxima* and *Lobularia maritima* from the Mediterranean, *Fuchsia magellanica* and *Bromus unioloides* from South America and *Mimulus moschatus* and *Helianthus annuus* from North America, are all naturalised in Britain (Clapham *et al.*, 1962), and South Australia.

(b) Plants unintentionally introduced, or native to Britain and introduced generally unintentionally to South Australia, e.g. *Amaranthus retroflexus*, *Coronopus didymus*, *Medicago polymorpha*. Species referred to as "cosmopolitan" would be included here.

Also, the possibility must be considered that some plants believed to have been introduced directly to South Australia may have come via Britain. Thus both *Cyperus tenellus* (Kloot, 1979) and *Solanum elaeagnifolium* were believed to have reached South Australia in

| ORIGIN | 1855 No. | 1855 Proportion | 1909 No. | 1909 Proportion | 1929 No. | 1929 Proportion | 1965 No. | 1965 Proportion | 1984 No. | 1984 Proportion |
|---|---|---|---|---|---|---|---|---|---|---|
| Mediterranean | 25 spp. | 25% | 128 spp. | 32% | 177 spp. | 33% | 264 spp. | 33% | 284 spp. | 31% |
| Europe[1] | 50 | 49 | 142 | 35 | 174 | 32 | 222 | 28 | 232 | 26 |
| Eurasia[1] | 9 | 9 | 28 | 7 | 31 | 6 | 39 | 5 | 41 | 5 |
| Asia | — | — | 2 | + | 4 | + | 5 | + | 11 | 1 |
| Eastern Asia | — | — | — | — | 1 | + | 9 | 1 | 11 | 1 |
| Old world tropics | — | — | 3 | + | 5 | 1 | 7 | + | 8 | + |
| California | 2 | 2 | 2 | + | 2 | + | 6 | + | 8 | + |
| North America[1] | 2 | 2 | 9 | 2 | 21 | 4 | 43 | 5 | 51 | 6 |
| Central America | 1 | 1 | 4 | + | 6 | 1 | 12 | 1 | 19 | 2 |
| South America | 4 | 4 | 18 | 5 | 27 | 5 | 51 | 6 | 63 | 7 |
| South Africa | 8 | 8 | 49 | 12 | 72 | 13 | 110 | 14 | 132 | 15 |
| East Africa | — | — | 1 | + | 3 | + | 7 | + | 9 | 1 |
| Western Australia | — | — | 1 | + | 1 | + | 3 | + | 5 | + |
| South Australia | — | — | 3 | + | 4 | + | 5 | + | 5 | + |
| Eastern Australia + N.Z. | — | — | 4 | + | 6 | 1 | 11 | 1 | 15 | 2 |
| Garden origin | — | — | 3 | + | 5 | 1 | 9 | 1 | 10 | 1 |
| TOTALS | 101 spp. | 100% | 397 spp. | 100% | 539 spp. | 100% | 803 spp. | 100% | 904 spp. | 100% |

([1] Excluding that area immediately preceding in the list; + Less than 1% of total).

Table 1: The origins of the naturalised flora of South Australia at different periods, derived from Kloot (1986).

contaminated fodder from South Africa and North America respectively, but both species were being grown in Britain by 1830 (Loudon, 1830).

(c) Plants intentionally moved directly to South Australia from their origin, e.g. *Pentzia virgata* introduced from South Africa, *Paspalum dilatatum* from South America, *Ehrharta* spp. from South Africa and *Medicago rugosa* from the Mediterranean as potential fodders.

(d) Plants unintentionally moved directly to South Australia from their native origin as fodder or ballast contaminants or attached to implements, etc., e.g. *Cyperus arenarius* from southern Asia; *Scirpus hamulosus* from central Asia in camel fodder or harnesses; *Eragrostis curvula* from South Africa, apparently as a contaminant of *Ehrharta* seed; *Emex australis* from South Africa as a fodder contaminant; *Galenia* spp. from South Africa and *Suaeda aegyptiaca* from Europe in ballast.

It is a feature of such species that they have never been recorded from Britain or other parts of north-western Europe with which South Australia has historical ties. Consequently very few of such plants are of temperate origin, but rather from Mediterranean or sub-tropical regions.

Even within Australia, a number of plants have been specifically documented as reaching South Australia via other States as illustrated by the following examples:

*Brassica tournefortii*, *Berkheya rigida* and *Emex spinosa* were apparently transported across the Transcontinental Railway from Western Australia. *Aster subulatus* and *Acroptilon repens* were recorded as moving down the Murray River valley from Victoria, whilst *Amsinckia hispida* was brought across the border in contaminated seed grain from the Wimmera and Mallee of Victoria to contiguous regions of South Australia. *Schismus barbatus* moved down the railway line from Broken Hill, New South Wales, while *Xanthium occidentale* and *Salvia reflexa* were introduced from Queensland through New South Wales.

## Manner of Introduction

Of the 904 species recorded as naturalised, 515 are either documented or suspected with good reason to have been introduced on purpose. A total of 214 species have been documented or are suspected of being accidentally introduced. The remaining species are uncertain at this stage. A further breakdown is as follows:

| | Intentional introduction | | Accidental introduction | | No. |
|---|---|---|---|---|---|
| | Documented | Suspected | Documented | Suspected | info. |
| Monocotyledons | 142 | 20 | 5 | 35 | 32 |
| Dicotyledons | 309 | 44 | 30 | 144 | 143 |
| Totals | 451 | 64 | 35 | 179 | 175 |

Thus 69% of the monocotyledonous species are documented or suspected of having been introduced intentionally as are 53% of the dicotyledonous species. Overall 57% were thus introduced. The group for which information is lacking can only add to these proportions should their means of introduction be determined in the future, but even now it is clear that the majority of naturalised aliens was intentionally introduced. This was not realised in the past and led to comments such as "Most introduced plants have entered the country fortuitously and without conscious human aid" (Trumble, 1949) or that weeds were "fellow travellers" (i.e. unintentional introductions) Parsons, 1981).

The following analysis reveals the overwhelming dominance of ornamentals as the means by which naturalised alien plants were first introduced.

| | Documented | Suspected | Totals |
|---|---|---|---|
| Ornamentals | 319 | 40 | 359 |
| Culinary plants | 43 | 1 | 44 |
| Medicinals | 8 | 5 | 13 |
| Hedges | 14 | — | 14 |
| Fodder plants | 58 | 17 | 75 |
| Others | 9 | 1 | 10 |
| Total | 451 | 64 | 515 |

It should be noted that many plants had multiple uses e.g. as hedges and ornamentals e.g. *Genista* spp., *Crataegus* spp. or as culinary and medicinal herbs, e.g. *Mentha* spp., *Taraxacum officinale*, but the categorisation shown here is derived from careful analysis or available data.

A similar analysis of the numbers of accidentally introduced species shows the following:

| | Confirmed | Possible (based on overseas records) | Total |
|---|---|---|---|
| Contaminated seed | 16 | 41 | 57 |
| Ballast plants | 7 | 36 | 43 |
| Contaminated footwear | — | 11 | 11 |
| Contaminated fodder | 3 | 3 | 6 |
| Attached to stock | 4 | 88 | 92 |
| Others | 5 | — | 5 |
| Total | 35 | 179 | 214 |

This leaves a further 175 species for which no information, even suggestive, has been located.

## Distribution Patterns of Aliens in South Australia

A number of different distribution patterns of naturalised alien plants in the State may be discerned. Within a particular type there is great variation, reflecting the dynamic nature of plant distribution. In some cases the range is so restricted or at least the data are so limited at present, that the potential distribution is still uncertain. Nevertheless, for many species it is apparent that the distributions may be restricted due to natural factors e.g. soil salinity, or management factors e.g. the extent of cropping.

The following comments relate to those species sufficiently widespread that a distribution pattern may be discerned.

### Ubiquitous

Many of the major weeds show an ubiquitous distribution pattern, being found very widely throughout the settled areas and extending to a greater or lesser extent into the interior. Some examples are *Lolium rigidum*, *Arctotheca calendula*, *Hypochoeris glabra*, *Sisymbrium orientale*, *Erodium cicutarium.*

### Maritime

Some plants are strictly maritime in distribution, being almost wholly confined to the strand itself or perhaps the first dune. Such species include *Cakile* spp., *Euphorbia paralias*, *Ammophila arenaria.*

Others are found predominantly near the sea but also in other saline areas inland. Such species include most local representatives of the Aizoaceae, *Puccinellia* spp., *Lolium loliaceum*, *Limonium* spp., *Dischisma arenarium.*

### Urban

Most of the species found about towns and settlements in general are garden escapes which have not or cannot spread into farmland, scrub, or land used for other purposes. Some examples are *Amaryllis belladonna*, *Aeonium arboreum* and *Cestrum parqui.*

Others are associated, at least so far, with transport such as *Ecballium elaterium* which is associated with railway lines. The compacted earth of roadsides, industrial yards and similar areas seems to favour certain species such as *Conyza bonariensis.*

One of the features of urban areas is the increased runoff from compacted or sealed ground surfaces as well as the enhanced watering of gardens. Consequently many species commonly found in such situations are also found in irrigation areas. *Aster subulatus* and *Chenopodium album* are but two examples.

*Cyperus rotundus* and *Dischisma capitatum* are two species mostly confined to the Adelaide urban area, although the former is found around other population centres and in irrigation areas. In metropolitan Adelaide they have been spread in garden loam and sand respectively and are restricted to the area serviced by that trade.

### Farming areas

Geographically the distributions are diverse in extent. Some approach the ubiquitous distributions already mentioned whilst others are restricted to only a small part of the settled areas, e.g. *Monopsis simplex* is found in a narrow band from Comaum through Penola to Millicent in the Lower South East, and *Glaucium flavum* is restricted to a belt of sandy country extending from Port Gawler to beyond Balaklava in the Lower North.

Some general patterns are obvious. *Avena fatua*, *Aira cupaniana*, *Bromus hordeaceus*, *Echium plantagineum*, *Hypochoeris radicata* and *Plantago lanceolata*, among others, are very widespread throughout the settled areas. Many species, however, show restricted distributions.

The following species are examples of well-established plants that are still largely confined to the South East: *Alopecurus myosuroides*, *Monopsis simplex*, *Anchusa capensis*, *Hirschfeldia incana*, *Euphorbia exigua*, *Blackstonia perfoliata*, *Lotus angustissimus*, *Trifolium stellatum* and *Reseda alba.* Conversely, there are plants widespread in the northern parts of the State but not found in the South East except as strays: *Bromus rubens*, *Schismus barbatus*, *Neatostema apulum*, *Calendula arvensis*, *Centaurea melitensis*, *Carrichtera annua*, *Rapistrum rugosum*, *Sisymbrium erysimoides*, *S. irio* and *Astragalus* spp. It is interesting to note that Black (1918) recognised that in the South East *Hirschfeldia incana* occupied the same ecological niche that *Rapistrum rugosum* occupied in the northern cereal areas.

Three plants are more or less restricted to the Mallee where they are well-established. *Lycopis arvensis*, *Silene apetala* and *Salvia lanigera* have shown little propensity to spread to other areas yet.

A few plants are widespread to the east of Spencer Gulf but are absent or almost so from Eyre Peninsula. They include *Amsinckia* spp., *Heliotropium europaeum*, *Centaurea calcitrapa* and *Reichardia tingitana.*

*Petrorhagia nanteulii* is the only alien species restricted to Kangaroo Island whilst *Dimorphotheca sinuata*, *Berkheya rigida*, *Iberis crenata* and *Withania somnifera* are only established on Eyre Peninsula, not having been found east of Spencer Gulf.

### Pastoral areas

There are a number of naturalised aliens that, at present, are well-established in the pastoral zone, although they may be found occasionally in the adjacent farming areas. Some are restricted to damp areas and are included below with aquatics. The others rely on natural rainfall, although they do better where this is supplemented by springs or roadside runoff. Such species include *Eragrostis barrelieri*, *Lamarckia aurea*, *Lophochloa pumila*, *Schismus arabicus*, *Heliotropium curassavicum*, *Sonchus tenerrimus*, *Alyssum linifolium*, *Argemone subfusiforme*, *Glaucium corniculatum*, *Rumex vesicarius* and *Myosurus minimus*.

### High rainfall areas

The high rainfall areas of South Australia, i.e. those receiving more than 400 mm rainfall per annum, are relatively small, being the southern-most part of Eyre Peninsula, the Mt Lofty Ranges and the Lower South East. Many species are restricted to these areas or even to only part of them. Some examples are most members of the Iridaceae, the Amaryllidaceae, *Cynosurus echinatus*, *Asclepias* spp., *Myosotis sylvatica*, *Rumex crispus*, *Rubus* spp. and *Tropaeolum majus*, and a number of woody species.

The soil types of high rainfall areas tend to be neutral to acidic and are never highly alkaline as found in the cereal growing areas. Furthermore, such areas are cooler, so that temperature, rainfall and soil type effects are confounded. Therefore it is uncertain which causal factor is limiting. It probably differs between species.

There is a small number of species which appear to require very high rainfall, by local standards. They are restricted to the immediate vicinity of Mt Lofty where the average annual rainfall exceeds 750 mm. They include *Agrostemma githago*, *Lychnis coronaria*, *Sambucus nigra*, *Cistus psilosepalus*, *Cardamine flexuosa* and *Crataegus sinaica*.

### Soil types

There are a number of species that are strongly confined to alkaline soils such as *Adonis microcarpus*, *Buglossoides arvensis* and *Bifora testiculata*. It could be argued that as in the higher rainfall areas, arid soil types are confounded with temperature and average annual rainfall. However Trumble and Donald (1938) and Kloot (1973) show that it is not so for *Medicago truncatula* and *Adonis microcarpus* respectively. The distributions of these plants are dependent on the alkalinity of the soil *per se*.

Experimental data obtained by the author (Kloot, 1985a) demonstrate the importance of soil characteristics in determining the distribution of alien plants in the Lower North of South Australia.

### Aquatics

There are three sub-groups within the small group of naturalised free-floating aquatics found in South Australia. *Ludwigia peploides* and *Potamogeton* spp. seem to be found in many water bodies. *Zanichellia palustris*, *Sagittaria graminea* and formerly, *Eichhornia crassipes*, have only been found in the River Murray. *Alisma lanceolatum* and *Aponogeton distachyon* have only been found in the westward-flowing rivers of the Mt Lofty Ranges. *Callitriche hamulata* has been recorded once from the South East. It is recorded from acidic water bodies in Europe (Landolt, 1977) so it is unlikely to invade the Murray system.

The case of *Sagittaria graminea* is particularly interesting. It has been found regularly in the River Murray upstream from Mannum since it was first collected in 1967, and was charted

in detail during an extensive survey in 1982 (R. Carter, pers. comm.). However, it has never been found further downstream, suggesting that environmental conditions below Mannum are not suitable for its establishment. A strong possibility would be the salinity of the river which increases throughout its course in South Australia. It is possible that in the vicinity of Mannum the level of salinity generally exceeds the threshold above which the plant will not grow. It would be interesting to see if there is any temporary establishment further downstream during prolonged flows of fresh water.

In the checklist of naturalised species (Kloot, 1986) 14 are listed as aquatics which are defined as free-floating plants and necessarily are restricted to water bodies. A further 10 species such as *Cyperus* spp. and *Agrostis gigantea* are only found in very wet environments but are not aquatics, as defined here. *Scirpus hamulosus* and *Cyperus laevigatus* are two examples of a further sub-group that inhabits the permanently damp patches around springs, etc. in the interior.

## Growth Form

Analyses of lists of native and introduced species in various plant associations in South Australia reveal that the native vegetation is predominantly perennial, but the successful aliens are mainly annual (Kloot, 1985b). This is understandable as an annual growth form will accommodate the two most prominent features of the South Australian environment, the short growing-season and the cycle of annual cultivation in the settled areas.

Because the areas of high rainfall (more than 500 mm per annum) are so restricted, occurring as three small, disjunct zones, only a very small proportion of the alien flora consists of shrubs and trees which need more humid conditions for survival than annuals. The scarcity of water bodies has similarly precluded the establishment of many aquatics.

The breakdown of the alien flora by growth form is as follows:

| | | |
|---|---|---|
| Annuals | 454 | 50.2% |
| Herb. perennials | 298 | 33.0 |
| Shrubs | 76 | 8.4 |
| Trees | 36 | 4.0 |
| Climbers | 24 | 2.7 |
| Aquatics | 14 | 1.5 |
| Parasites | 2 | 0.2 |
| | 904 | 100.0% |

The preponderance of perennials in the South Australian native flora may be shown by examining the ratios of annual to perennial species. In the four land systems considered by Specht (1972) the ratios are as follows:

| | Ratio of annual/perennial species | | |
|---|---|---|---|
| | **Native species** | **Introduced species** | **All species** |
| Sclerophyll | .037 | 1.06 | .088 |
| Mallee | .064 | 3.44 | .141 |
| Arid Lands | .261 | * | .289 |
| Savannah | .157 | 1.74 | .460 |

* There are no perennial species in this category.

Comparable figures given by Barbour *et al.* (1981) for Israel, the Mediterranean generally and California are as follows:-

| | Israel coastal | Israel desert | Mediterranean | Californian coastal |
|---|---|---|---|---|
| A/P ratio | 1.60 | 0.69 | 1.06 | 0.43 |

From these figures it is clear that the ratios for native Australian communities are very low. The invasion of aliens increases the ratios, that of the savannah system exceeding that of the Californian coastal dunes, but still well below those of Israel and the Mediterranean generally to which the ratios of the introduced species are more comparable.

Because of their ability to take advantage of even shorter term opportunities, a high proportion of annuals in a plant community would be advantageous in ensuring that the community itself could recolonise any grossly disturbed areas rather than leave them available to alien invaders.

## The Importance of Aliens in the South Australian Flora

Based on the checklist, the following figures demonstrate the degree of naturalisation of the alien flora.

| | | |
|---|---|---|
| Established* | 452 spp. | 50.0% |
| Adventive | 283 | 31.3 |
| Casual | 169 | 18.7 |
| | 904 spp. | 100.0% |

*As defined previously (Kloot, 1987a)

Schomburgk (1878) listed over 8000 species growing in the Adelaide Botanic Gardens, most of which were exotic. Allowing arbitrarily that 2000 extra species not recorded by Schomburgk were introduced by others, either prior to or after that time, then less then 10% of the introduced species have become naturalised to any extent and less than 5% have become established. These figures agree with estimates made on a national basis (R.H. Groves, pers. comm.).

The breakdown of these categories according to growth forms (Table 2) emphasises the success of annual plants, in particular, and herbaceous perennials to a lesser extent, compared to shrubs and trees for the reasons canvassed above. Established annuals is the largest single category in that Table and they alone comprise 31.6% of the alien flora.

A further analysis was made of the degree of naturalisation with respect to accidental and intentional introductions and is presented in Table 3. The proportion of plants accidentally introduced that have become established (65%) is greater than the proportion of those intentionally introduced that have become so (39%). If they are able to grow at all in our environment, then if they are "weedy" enough to arrive here unaided, it is likely that they have the "weedy" characteristics (Baker, 1974) to spread and become completely naturalised.

All species were categorised further as being insignificant, minor or major weeds. The first category includes most persistent or escaped crop plants for the assessment was made solely on perceived negative aspects of naturalised populations. Therefore *Triticum aestivum* was regarded as insignificant because outside cultivation it is of no significance to landholders.

In the following figures the "minor" and "major" categories have been subdivided into those species "intentionally" and "unintentionally" introduced.

| | Annuals | | | Herbaceous Perennials | | | Shrubs | | | Trees | | | Climbers | | | Aquatics | | | Parasites | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E* | A | C | E | A | C | E | A | C | E | A | C | E | A | C | E | A | C | E | A | C |
| Monocotyledons | 58 | 11 | 13 | 55 | 58 | 30 | | 1 | 1 | | | | | | | 5 | 2 | | | | |
| Dicotyledons | 226 | 80 | 66 | 70 | 48 | 37 | 20 | 43 | 10 | 8 | 24 | 4 | 5 | 12 | 7 | 4 | 2 | 1 | 1 | 1 | — |
| Totals | 284 | 91 | 79 | 125 | 106 | 67 | 20 | 45 | 11 | 8 | 24 | 4 | 5 | 12 | 7 | 9 | 4 | 1 | 1 | 1 | — |
| Percentages of each growth form | 62.6 | 20.0 | 17.4 | 41.9 | 35.6 | 22.5 | 26.3 | 59.2 | 14.5 | 22.2 | 66.7 | 11.1 | 20.8 | 50.0 | 29.2 | 64.3 | 28.6 | 7.1 | 50.0 | 50.0 | — |

(* E = Established, A = Adventive, C = Casual as defined earlier (Kloot, 1987a).)

Table 2: The degree of naturalisation of the alien flora of South Australia as influenced by growth form.

| | Intentionally Introduced | | | Unintentionally Introduced | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|
| | E* | A | C | E | A | C | E | A | C |
| Monocotyledons | 66 | 57 | 33 | 53 | 15 | 11 | 119 | 72 | 44 |
| Dicotyledons | 133 | 151 | 75 | 200 | 60 | 50 | 333 | 211 | 125 |
| Totals | 199 | 208 | 108 | 253 | 75 | 61 | 452 | 283 | 169 |
| | — | 515 | — | — | 389 | — | — | 904 | — |

* E = Established, A = Adventive, C = Casual, as defined earlier (Kloot, 1987a)

Table 3: The degree of naturalisation of the alien flora as influenced by means of introduction.

| | Insignificant | Minor weed | | Major weed | | Total |
|---|---|---|---|---|---|---|
| | | Intentionally introduced | Unintentionally introduced | Intentionally introduced | Unintentionally introduced | |
| Monocotyledons | 170 | 28 | 11 | 12 | 13 | 234 |
| Dicotyledons | 354 | 131 | 99 | 31 | 55 | 670 |
| TOTALS | 524 | 159 | 110 | 43 | 68 | 904 |
| | | 269 | | 111 | | |

It is clear that the majority of major weeds was accidentally introduced. Those plants having the "weediness" to move successfully without the intentional assistance of Man are those most likely to succeed in a new environment (Baker, 1974).

For various reasons (Kloot, 1985b) native plant communities are unable to stand disturbance and degenerate as a result of European activities. Although Moore (1957) concluded that in south-eastern Australia introduced species do not invade undisturbed climax communities, his finding is of limited applicability, particularly in South Australia. Firstly, truly undisturbed communities are almost non-existent (Bridgewater & Kaeshagen, 1979). Even in places where gross disturbances such as ploughing or timber-getting have not occurred and relatively benign activities such as light grazing or the movement of people and their belongings have left the vegetation more or less intact, alien species have been introduced. They tend to form only a minor part of the flora, although this varies between different land systems.

Secondly, the communities studied by Moore are found in relatively high rainfall areas (>400 mm p.a.) compared to those of South Australia (100-400 mm p.a.) which consequently have slower growth rates. Such communities do not have as much resilience to counter disturbance.

Further analysis of the data derived from Specht (1972) presented by Kloot (1985b, Table 1) reveals the following:

| | No. of species | | |
|---|---|---|---|
| | Native | Introduced | % Introduced = Invasion index (Bridgewater & Kaeshagen, 1979) |
| Sclerophyll | 336 | 35 | 9.4 |
| Mallee | 414 | 40 | 8.8 |
| Arid Lands | 227 | 5 | 2.2 |
| Savannah | 258 | 145 | 36.0 |

The proportion of introduced species in the vegetation of Californian sand dunes is 14% (Barbour *et al.*, 1981). By comparison, in coastal dunes in Israel the porportion is about 1% (*Ibid.*). This is further support for the view (Kloot, 1985b) that the present flora of the Middle East is better adapted to withstand competition than the Australian flora, or for that matter, the Californian flora, having developed during a much longer history of traumatic disturbance (>100,000 year cf. <10,000 years, (*Ibid.*).

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## References

Bailey, J. (1845). Catalogue of plants cultivated in and for sale at the Hackney Nursery, Adelaide, 1945. *The Adelaide Observer*, 3.v.1845, pp 1-2.

Baker, H.G. (1974). The evolution of weeds. *Ann. Rev. Ecol. & Syst.* 5: 1-24.

Barbour, M.G., Shmida, A., Johnson, A.F. & Holton, B. (1981). Comparison of coastal dune scrub in Israel and California: physiognomy, association patterns, species richness, phytogeography. *Isr. J. Bot.* 30: 181-198.

Black, J.M. (1918). Additions to the flora of South Australia, No. 14. *Trans. Proc. Royal Soc. S. Aust.* 42: 168-184.

Bridgewater, P.B. & Kaeshagen, D. (1979). Changes induced by adventive species in Australian plant communities, in O. Wilmans & R. Tuxen (eds) "Werden und Vergehen van Pflanzengesellschaften". (Cramer: Vaduz).

Charlwood, D. (1981). "The Long Farewell". (Allen Lane: Ringwood).

Clapham, A.R., Tutin, T.G. & Warburg, E.F. (1962). "Flora of the British Isles," 2nd ed. (Univ. Press: Cambridge).

Everist, S.L. (1959). Strangers within the gates. *Qld. Natural.* 16: 49-60.

Gulmon, S.L. (1977). A comparative study of the grassland of California and Chile. *Flora* 166: 261-278.

Kleinschmidt, H.E. & Johnson, R.W. (1977). "Weeds of Queensland". (Govt Printer: Brisbane).

Kloot, P.M. (1973). Studies in the ecology of *Adonis microcarpus*. M. Ag. Sc. Thesis, University of Adelaide.

Kloot, P.M. (1979). The native and naturalised *Cyperus* species in South Australia. *J. Adelaide Bot. Gard.* 1: 333-341.

Kloot, P.M. (1983). Early records of alien plants naturalised in South Australia. *J. Adelaide Bot. Gard.* 6: 93-131.

Kloot, P.M. (1984). The introduced elements of the flora of southern Australia. *J. Biogeogr.* 11: 63-78.

Kloot, P.M. (1985a). Studies in the alien flora of the cereal rotation areas of South Australia. Ph.D. Thesis, University of Adelaide.

Kloot, P.M. (1985b). The spread of native Australian plants as weeds in South Australia and other Mediterranean regions. *J. Adelaide Bot. Gard.* 7: 145-157.

Kloot, P.M. (1986). Checklist of the introduced species naturalised in South Australia. *S.A. Dept. Agric. Tech. Paper* No. 14.

Kloot, P.M. (1987a). The naturalised flora of South Australia. 1. The documentation of its development. *J. Adelaide Bot. Gard.* 10: 81-90.

Kloot, P.M. (1987b). The naturalised flora of South Australia. 2. Its development through time. *J. Adelaide Bot. Gard.* 10: 91-98.

Landolt, E. (1977). "Oekologische Zeigerwert zur Schweizer Flora". (Geobotanisches Inst.: Zürich).

Loudon, J.C. (1830). "Loudon's Hortus Brittanicus". (Longman: London).

McEwin, G. (1843). Catalogue of plants grown at Melbourne Cottage, North Adelaide, in J. Allen (ed.) "The South Australian Almanack and General Directory for 1844". (Allen: Adelaide).

Michael, P.W. (1972). The weeds themselves — early history and identification, in History of Weeds Research in Australia symposium. *Proc. Weed Soc. N.S.W.* 5: 3-18.

Moore, R.M. (1957). Some ecological aspects of the weed problem in Australia. *Proc. 4th Inter. Congr. Crop Prot., Hamburg* 1: 447-449.

Naveh, Z. (1967). Mediterranean ecosystems and vegetation types in California and Israel. *Ecology* 48: 445-459.

Parsons, W.T. (1981). The history of introduced plants, in D.J. & S.G.M. Carr (eds)"Plants and Man in Australia". (Academic Press: Sydney).

Schomburgk, R. (1878). "Catalogue of the Plants under Cultivation in the Government Botanic Gardens, Adelaide, South Australia". (Govt Printer: Adelaide).

Solbrig, O. *et al.* (1977). Cited by M.L. Cody & H.A. Mooney (1978). Convergence versus non-convergence in mediterranean-climate ecosystems. *Ann. Rev. Ecol. Syst.* 9: 265-321.

Specht, R.L. (1972). "The Vegetation of South Australia", 2nd ed. (Govt Printer: Adelaide).

Trumble, H.C. (1949). The ecological relations of pastures in South Australia. *J. Brit. Grassl. Soc.* 4: 135-160.

Trumble, H.C. & Donald, C.M. (1938). Soil factors in relation to the distribution of subterranean clover and some alternative legumes. *J. Aust. Inst. Agric. Sci.* 4: 206-208.

Tutin, T.G. *et al.* (1964-80). "Flora Europaea", 5 vols. (Univ. Press: Cambridge).

Wells, M.J. & Stirton, C.H. (1982). South Africa, in W. Holzner & M. Numata (eds.) "Biology and Ecology of Weeds". (Junk: The Hague).

Willis, J.H. (1972). "A Handbook to Plants in Victoria", vol. 2 (Univ Press: Melbourne).